Title: Safeguards by Design Challenge Final Report - FY19 University of Rhode Island University of Texas - Austin

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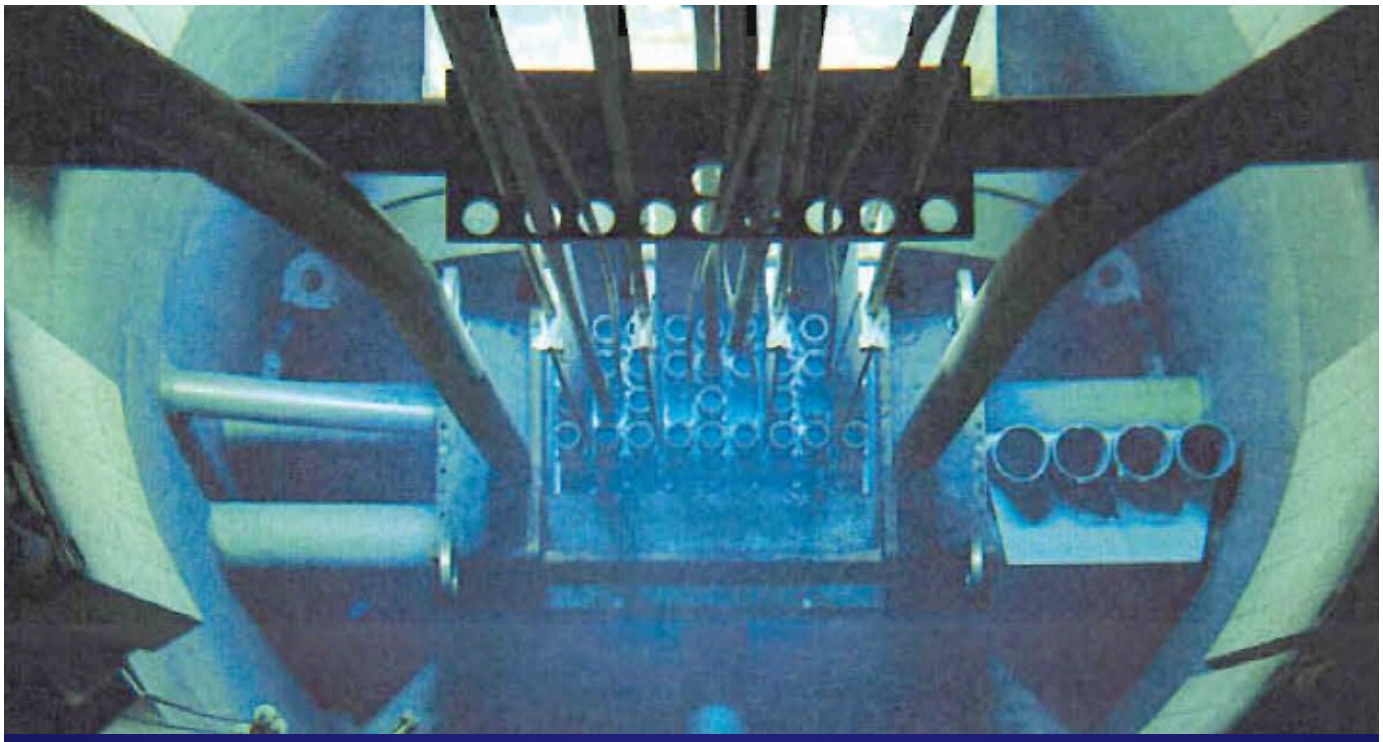

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University of Rhode Island

University of Texas - Austin

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Los Alamos NATIONAL LABORATORY EST. 1943

Table of Contents

Cover contains a photo of LANL's Omega West Reactor (OWR), taken from LANL report LA-UR-04-6681.

Safeguards by Design Challenge Final Report- FY19

1. Project Summary

This University Engagement project challenged engineering students at universities, without nuclear engineering degrees but with research reactors, to incorporate Safeguards by Design concepts into their Senior Capstone Design Project. This University Engagement project was part of the U. S. Department of Energy's (DOE) National Nuclear Security Administration (NNSA), Office of Defense Nuclear Nonproliferation, Office of International Nuclear Safeguards, Next Generation Safeguards Initiative, Human Capital Development: University Engagement Program. This program exposed university students with Mechanical Engineering major and Nuclear Engineering minors to the concepts of international nuclear safeguards.

FY19, three teams at the University of Rhode Island and one team at the University of Texas - Austin participated in researching, designing, building, and testing projects to support international nuclear safeguards measurements or verification. The projects involved engaging in activities at the university's research reactors. All the projects engaged students with prototyping a design and/or tool for application at the Universities' Research Reactor. At the end of the course, most of the students expressed the experience was a positive and they learned more about international nuclear safeguards and applying requirements than they had previously encountered.

2. Merit to Human Capital Development (HCD)

These university challenges directly contributed to the HCD mission by introducing students from the broad engineering field to safeguards concepts and approaches as part of their engineering senior level design course. Unlike nuclear engineering or other safeguards-focusing majors, the students had no knowledge of safeguards, non-proliferation, or the IAEA before initiating their projects. Using the senior capstone project is a great venue for the students to get hands on experience incorporating safeguards needs into their designs and seeing how those needs interact with the engineering requirements that are more standard. The students not only learn about safeguards, but also learn that they can contribute to the safeguards mission. Nuclear safeguards can only reach its full potential in terms of cost and resource savings if all the different voices during the planning and construction phases of a facility are aware of all the requirements and incorporate them in the design phases.

3. FY 19 Design Challenge Projects:

Challenge 1: Development of a Nuclear Fuel Handling Device for Pool Research Reactors

Nuclear fuel rods in research reactors is typically handled manually. The fuel needs to be inspected on a periodic basis for cracks and other defects. Additionally, safeguards require that the fuel is accounted for at a minimum annually. The fuel throughput is not large enough annually to investigate the use of an automated system; and automated systems would interfere with the control of the reactor. The previously used poles had defects that hindered operator use. Poles that bend are hard to line-up with the fuel in the reactor pool. When the pole bends there is optical distortions for the operator to line up the pole. Heavy poles have negative ergonomic impact on operators. The task is to build a 30-foot pole for use by operators of the RINSC Pool Research Reactor that will make fuel inspections easier, and more efficient.

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Challenge 2: Research Reactor Fuel Inspection Rover

The current method for examining fuel at the Rhode Island Nuclear Science Center (RINSC) is to use a camera above the pool surface and zoom in. This is not an efficient nor effective method for examining fuel rods. Any ripples in the surface of the pool causes distortions in the camera field of view. The use of an underwater camera would aid the pool operators in making more efficient and accurate inventories of the nuclear fuel in the pool, by being better able to read the inventory numbers on the fuel rods. The challenging part is to have a design that will take into consideration the camera degradation in the high gamma fields. Additionally, the device needs to operate to a depth of 30 feet and needs to be controlled, so that it does not interfere with reactor operations (maybe tethered). Also, the device needs to be waterproof.

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Challenge 3: Design for a Neutron Radiography Facility for Fuel Measurements and Inspections

Neutron radiography is a useful tool for looking at used/spent/irradiated nuclear fuel. This device can find cracks in the fuel rod cladding, additionally with neutron radiography can reveal the nuclear material content of the fuel. Currently spent fuel content is typically calculated based on reactor operation. Determine reactor operation time and conditions is challenging for research reactors because the reactor is shut on and off more frequently, fuel is moved around more frequently, and often to fuel rods can be flipped for improved performance. Measurements of actual nuclear material content in the fuel rod would support international nuclear safegurads, and improve nuclear material accounting. The task for the students was to design a neutron radiography facility that could be part of the RINSC, for better fuel nuclear material accounting and photographic radiography for fuel inspection to look for defects in the fuel rod cladding.

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Challenge 4: Development of a Capability to Use Gamma Measurements for Nuclear Fuel Confirmation Measurements in a TRIGA Reactor Pool

It is critical to global security to ensure that nuclear materials are not diverted from civilian nuclear facilities for military purposes. A system of safeguards is used to verify the completeness and correctness of a State's declaration of their nuclear materials and nuclear activities. Due to the highly variable and adaptable nature of research reactors, the verification of the nuclear material content of nuclear can be challenging. For the University of Texas at Austin Nuclear Engineering Teaching Laboratory (NETL) reactor this issue is further complicated by the progeny of its fuel materials. All of the fuel used by the NETL was previously irradiated at another facility prior to its receipt. Thus, there is a larger than desirable uncertainty associated with the nuclear material content of the fuel used at the NETL.

Nuclear fuels are typically characterized by their burnup, irradiation time, cooling time, and initial ^{235}U enrichment. Burnup is measured in energy produced by the fuel per unit mass of initial uranium. Knowledge of the characteristics listed above are useful in correlating nuclear material content of the used fuel (specifically ^{235}U and Pu mass). Measurements of several fission product gamma-ray signatures together are useful for extracting knowledge of the fuel. Thus, a system that quantitatively measures gamma-rays emitted from the TRIGA fuel may provide the ability to characterize the nuclear material content for international nuclear safeguards. The team task was to design a system for measuring used nuclear fuel at the NETL TRIGA reactor, build and demonstrate a prototype system.

4. FY19 University Engagements:

University of Rhode Island:

LANL and the University of Rhode Island (URI) are working three projects for the 2018-2019 school year. These projects go over two semesters. Each project team consists of four students. Additionally, the focus for the projects for this school year was using the Rhode Island Nuclear Science Center (RINSC) which houses a General Electric 2 mega-watt (MW), light water cooled, pool type reactor. See Figure 1. The URI Senior Design Course covers two semesters (a full school year).

Figure 1. Photographic showing Rhode Island Nuclear Science Center (RINSC) and the General Electric Research Reactor.

Professors and Staff:

- Prof. Dr. Bahram Nassersharif: University of Rhode Island, Dept of Mechanical Engineering,
- Prof. Cameron Goodwin: University of Rhode Island, Dept of Mechanical Engineering, & Director, Rhode Island Nuclear Science Center;

University of Texas-Austin:

LANL and the University of Texas-Austin (UT-A) worked one project for the spring 2019 semester. The project team consisted of four students. Additionally, the focus for the project was using the research reactor at the Nuclear Engineering Teaching Laboratory (NETL) located on the J.J. Pickle Research Campus. The reactor is a 1 MW TRIGA (Training, Research, Isotopes, General Atomics) Mark II Research Reactor. See Figure 2. As other TRIGA reactors were shut down across the country, UT-A accepted fuel from the reactors. There is limited history on this fuel, so NETL has a true safeguards need to be able to identify the nuclear material content of the fuel.

Figure 2. Photographic showing location of UT's Nuclear Engineering and Testing Laboratory (NETL) and the inside of the TRIGA Research Reactor.[1]

Professors and Staff:

- Prof. Richard Crawford: *Earl N. & Margaret Brasfield Endowed Faculty Fellowship in Engineering*, University of Texas at Austin, Department of Mechanical Engineering
- Prof. William Charlton: *John J. McKetta Energy Professor,* University of Texas at Austin, Department of Mechanical Engineering and Director, Nuclear Engineering Teaching Laboratory- NETL.
- Larry Hall, Reactor Manager: University of Texas at Austin, Department of Nuclear Engineering (Nuclear Engineering Teaching Laboratory- NETL_

5. FY19 Project Updates and Photographs

University of Rhode Island

Presentation at Winter ANS Meeting

Two of the FY18 student projects were presented at the fall 2018 American Nuclear Society (ANS) Winter Meeting & Expo in Orlando Florida on November 12.

> "Design for Safeguards of Nuclear Facilities—Online HEPA Filter Replacement System," Joshua J. Bolt, Matthew J. Carlson, David L. Kehoe, Bahram Nassersharif (Univ. Rhode Island), Christy Ruggiero, Carolynn P. Scherer (LANL)
>
> "Design for Safeguards of System for Transfer of Spent Nuclear Fuel Assembly from Containment to Storage Building," Elio A. Manzi, Ryan P. Sullivan. Mathew G. Monfils, Jordan M. Kantor, Bahram Nassersharif (Univ. Rhode Island), Eric B. Rauch, Carolynn P. Scherer (LANL)

Student Senior Design Projects

The FY19 students designed and built a nuclear fuel handling device for pool research reactors that assisted the operator in meeting international nuclear safeguards requirements and NRC safeguards and safety requirements. The tool is currently in use at the RINSC. See Figure 3.

[1] Picture on left taken from: https://en.wikipedia.org/wiki/J._J._Pickle_Research_Campus

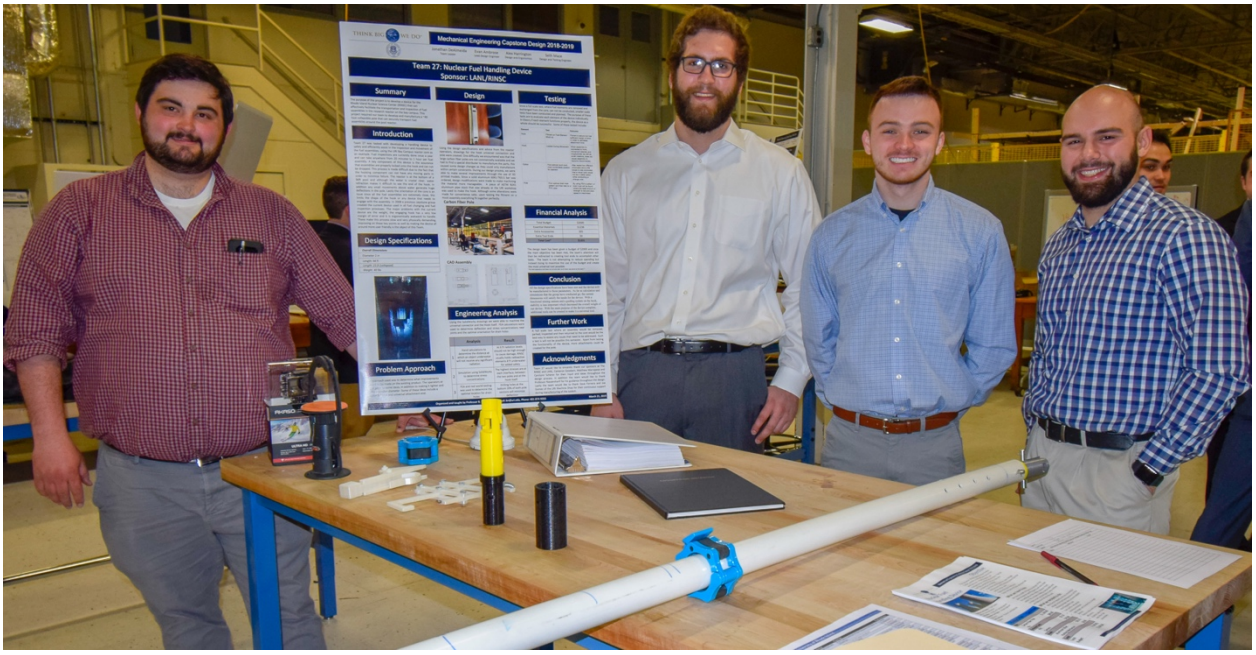

Figure 3. Student Team Members: Evan D. Ambrose, Jonathan C. Dealmeida, Alexander P. Harrington, and Seth David Mace

The students designed and built a rover for that could operate underwater to inspect nuclear fuel remotely in pool research reactors meeting international nuclear safeguards requirements and U.S. NRC safeguards and safety regulations. The students realized that the current design has some limits. This project will continue in FY20 to build a better prototype based on past experience and to incorporate additional features such as a gamma instrument for measuring the nuclear content in the fuel. See Figure 4.

Figure 4. Student Team Members: Brett J Cody, Matt Richard Hahn, Trevor L Pierce, and Cyrus Lewis Tyler.

The students had a design project, that they completed; there was no prototype. The design was for a neutron radiography facility that would be attached to the reactor vessel, using the neutrons to perform radiography of fuel that is out of the reactor pool. The students completed phase I of the design project and this project will continue next school year, 2019-2020 with Phase II of the

design. See Figure 5.

Figure 5. Student Team Members: Nicholas E. Azzarto, Jonathan Fuentes, and Nick Anthony Lian

University of Texas – Austin

The UT-A team invited LANL out to participate and the testing of the prototype tool for taking gamma measurements on fuel stored in the reactor pool. LANL participated in the demonstration on April 19, 2019 at the NETL. See Figure 6 for photos showing the testing of the prototype tool, and Figure 7 for a photo of the design team. The student demonstration successfully took gamma measurements on the nuclear fuel rod. This project will continue next school year as Phase II, to add a neutron capability to the tool.

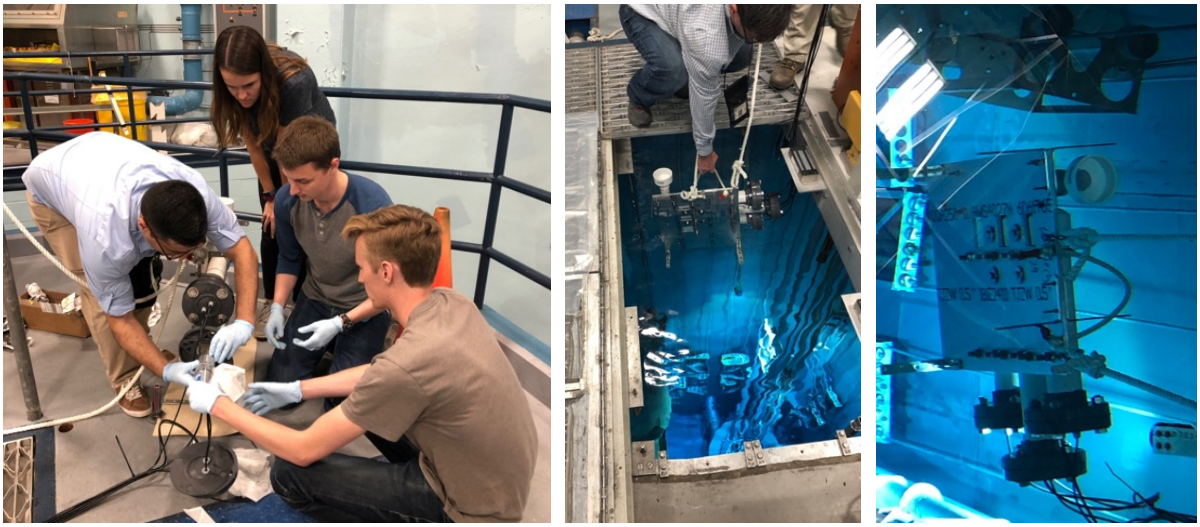

Figure 6. Students testing their prototype fuel rod measurement system in the reactor pool.

Figure 7. UT-Austin Nuclear Fuel Rod Measurement Team standing on the research reactor; left to right: Professor William Charlton, Carolynn Scherer (LANL), students: Benjamin Roensch, Daniel Penley, Megan Jones, and Axel Durham, and NETL reactor operator.

Interim design reports and final reports for all project are available at LANL.

6. Travel

October 25, 2019: Carolynn Scherer traveled to University of Rhode Island, located in South Kingston, RI, to meet with the students and give a presentation. Scherer met with all 3 design teams separately and worked with them on their designs and covered topical areas for incorporating nuclear safeguards into their design. Additionally, Scherer met with Dr. Goodwin at the RINSC to better understand how the projects were coordinated with the research reactor facility.

April 19, 2019: Carolynn Scherer traveled to the University of Texas-Austin for the Design Presentations and for prototype testing of the fuel measurement tool.

May 1, 2019: Carolynn Scherer traveled to University of Rhode Island for a presentation by the student teams of the 3 capstone projects. All 3 teams did a fantastic job designing and testing the challenges; additionally, a graduate student plans to further the design of one of the projects and present it at the Fall American Nuclear Society (ANS) meeting. In total 12 students worked on these projects. All the students were happy with the results and learning more about safeguards. Furthermore, we plan to proceed with 3 projects for the next school year 2019/2020. All produced final posters and design reports.

7. FY20 Quarter 1 Planned Activities:

Pending Travel:

Oct 2019, Rhode Island: LANL is planning a visit to URI October 17, 2019 to meet the project students for the FY19-FY20 school year, and have them present their preliminary project research. LANL staff will work directly with each student group on understanding international nuclear safeguards and applications to their projects. Additionally, LANL staff will probably make a presentation on international nuclear safeguards to one or more classes.

Contracting

All work at the universities is through LANL contracting. The university's charge a fee to participate in their Capstone or Senior Design Courses. LANL began the contracting process at the end of FY19 and will continue with the placement of the contracts at the beginning of FY20.

Student ANS Presentation

URI plans to present one of the projects from the FY19 projects at the ANS Winter Meeting & Expo, Washington, D.C., November 17-21, 2019.

> "Safety and Safeguards by Design – Design of a Fuel Handling Device for Open-Pool Research Reactors," Bahram Nassersharif, Jonathan DeAlmeida, Seth Mace, Alex Harrington, Evan Ambrose, Cameron Goodwin, and Carolynn Scherer

New Engagements

LANL will look into new engagements with the University of Maryland. They have a General Atomics 250 kW TRIGA Reactor located at the Maryland University Training Reactor (MUTR). The university has only a nuclear engineering minor, which is open to any students in the Clark School of Engineering. We have a contact, Katrina Groth.

Mentoring

LANL uses Guest Scientist, James Sprinkle, a LANL retiree, to work with the students. Dr. Sprinkle worked at the International Atomic Energy Agency (IAEA) in the Safeguards Department.

8. FY20 Capstone Projects:

Challenge 1: URI Research Reactor Fuel Inspection Rover (Phase II)

This project will build on last year's project (FY19), for examining nuclear fuel in the reactor pool at the Rhode Island Nuclear Science Center (RINSC). The rover will incorporate a camera to examine fuel. The use of an underwater camera would aid the pool operators in making more efficient and accurate inventories of the nuclear fuel in the pool, by being better able to read the inventory numbers on the fuel rods. The challenging part is to have a design that will take into consideration the camera degradation in the high gamma fields. Additionally, the device needs to operate to a depth of 30 feet and needs to be controlled, so that it does not interfere with reactor operations (maybe tethered). Also, the device needs to be waterproof. Building on lessons learned from the FY19 project the team will design a rover with one motor instead of 4 for directing and driving the rover. This project directly supports international nuclear safeguards in nuclear fuel inventory taking (PIT), specifically item identification.

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Challenge 2: URI Research Reactor Fuel Analysis Rover

The student design team will work with the Challenge 1 team in incorporating the capability to add

gamma instrumentation to the rover in order to make nuclear material measurements on the fuel in the reactor pool. These gamma measurements will be useful in calculating the nuclear material content of the fuel and for better nuclear material inventory of the fuel. This project directly supports international nuclear safeguards in nuclear fuel inventory taking (PIT), specifically in the area of nuclear material inventory.

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Challenge 3: URI Design for a Neutron Radiography Facility for Fuel Measurements and Inspections (Phase II)

Neutron radiography is a useful tool for looking at used/spent/irradiated nuclear fuel. This device can find cracks in the fuel rod cladding, additionally with neutron radiography can reveal the nuclear material content of the fuel. Currently spent fuel content is typically calculated based on reactor operation. Determine reactor operation time and conditions is challenging for research reactors because the reactor is shut on and off more frequently, fuel is moved around more frequently, and often to fuel rods can be flipped for improved performance. Measurements of actual nuclear material content in the fuel rod would support international nuclear safegurads, and improve nuclear material accounting. The task for the students was to design a neutron radiography facility that could be part of the RINSC, for better fuel nuclear material accounting and photographic radiography for fuel inspection to look for defects in the fuel rod cladding. This project directly supports international nuclear safeguards in nuclear fuel inventory taking (PIT), specifically in the area of nuclear material inventory.

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Challenge 4: UR-A Development of a Capability to Use Gamma Measurements for Nuclear Fuel Confirmation Measurements in a TRIGA Reactor Pool (Phase II)

The FY19 team developed an instrument with 3 ports (tubes) for making fuel measurements. The team used one port for connecting a gamma detector (good for uranium measurements) and making gamma measurements. For Phase II the team will work on connecting a neutron detector for making neutron measurements (better for plutonium measurements). They may also work to incorporate a camera in the third port. A system capable of quantitatively measuring neutrons emitted from the UT-NETL used fuel may provide the ability to characterize the nuclear material content for international nuclear safeguards. The team task will be to incorporate neutron measurement instrumentation into the Phase I prototype for measuring used nuclear fuel at TRIGA reactor and demonstrate a prototype system. This project directly supports international nuclear safeguards in nuclear fuel inventory taking (PIT), specifically in the area of nuclear material inventory.

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